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December 22, 2000

RECEIVED
JAN 23 2001
Federal Communications Commission
Office of Secretary

94-102

Magalie Roman Salas, Secretary
Federal Communications Commission
445 Twelfth Street, S.W.
Washington, D.C. 20554

Attn: Wendy Austrie, Policy Division, Wireless Telecommunications Bureau

Re: Choice Wireless, LC
Supplement to Choice Wireless, LC's Carrier Report on Implementation of Wireless E911 Phase II Automatic Location Identification - CC Docket No. 94-102

Dear Ms. Salas:

Choice Wireless, LC ("Choice") hereby supplements its report on implementation of Wireless E911 Phase II Automatic Location Identification ("ALI") (CC Docket No. 94-102) that was submitted on November 9, 2000, in response to the Federal Communications Commission's letter dated December 7, 2000.[1]

As explained in its initial report, Choice began offering wireless service on November 1, 2000. Accordingly, Choice was not required to obtain a TRS number by the November 9, 2000 filing date. However, pursuant to the Commission's request, Choice has now applied for a TRS number and will provide the number after it is issued by NECA (see redacted copy of application attached as Attachment 1).

Choice has chosen to utilize a handset-based technology. As stated in its November 9, 2000 report, it has not yet determined which particular vendor to use but is considering Tendler Cellular because its products are designed for the rural market (see Attachment 2). However, Choice's facilities utilize a GSM technology and Tendler Cellular does not yet have a product that is available in GSM phones. Therefore, Choice is also considering SnapTrack's products which have been tested in a GSM environment (see Attachments 3 & 4).

---

[1] A facsimile copy of the Declaration by an authorized company representative attesting to the accuracy of this report is attached. A supplemental filing will be made after the original has been received.

Choice currently has a very small number of handsets in operation as it has been in service for less than two months. The company plans to activate ALI-capable handsets in such a way that it meets the Commission's deployment schedule and that by December 31, 2005, 95 percent of all of its handsets will be ALI-capable.

Please let us know if you have any questions regarding this report.

By: ____________________
Tamber Ray
John Kuykendall
Its Attorneys

Kraskin, Lesse & Cosson, LLP
2120 L Street, N.W.
Suite 520
Washington, D.C. 20037
(202) 296-8890

Attachments

## DECLARATION

I, Alvin Fuhrman, President of Choice Wireless, LC ("Choice"), do hereby declare under penalties of perjury that I have read the foregoing "Supplement to Choice Wireless, LC Carrier Report on Implementation of Wireless E911 Phase II Automatic Location Identification" and the information contained therein that pertains to Choice is true and accurate to the best of my knowledge, information and belief.

Date: 12-21-00

Alvin M Fuhrman
Alvin Fuhrman, President

# ATTACHMENT 1

# 2000 FCC Form 499-S Telecommunications Reporting Worksheet

Approval by OMB 3060-0855

>>> Please read instructions before completing <<<

Short Form -- Universal Service Contributors only -- due September 1, 2000

**Block 1: Contributor Identification Information** — 101 Filer 499 ID

102 Legal name of reporting entity: Choice Wireless, L.C.

103 IRS employer identification number: [redacted]

104 Name telecommunications service provider is doing business as: AmeriLink

105 Principal communications business (check the one that best describes the reporting entity -- see directions):

- [ ] CAP/CLEC
- [x] Cellular/PCS/SMR (wireless telephony incl. by resale)
- [ ] Incumbent LEC
- [ ] IXC
- [ ] Local Reseller
- [ ] OSP
- [ ] Paging & Messaging
- [ ] Payphone Service Provider
- [ ] Pre-paid Card
- [ ] Private Service Provider
- [ ] Satellite
- [ ] Shared Tenant Service Provider
- [ ] SMR (dispatch)
- [ ] Toll Reseller
- [ ] Wireless Data
- [ ] Other Local
- [ ] Other Mobile
- [ ] Other Toll

If you check 'Other Local', 'Other Mobile' or 'Other Toll', describe your carrier type / services provided:

106 Holding company (All affiliated companies should show same name here):

107 FCC Registration Number (FRN) (not required for September 2000 filing):

108 Complete mailing address of reporting entity corporate headquarters: 205 N. Walnut Street, Muenster, TX 76252

**Block 2: Contact Information**

109 Person who completed this worksheet: Pam Tucholke

110 Telephone number of this person: (952 ) 942-7650

111 Fax number of this person: (952 ) 942-5938

112 E-mail of this person: PAM_TUCHOLKE QUANTUMCOMM.COM

113 Corporate office, attn. name, and mailing address to which future Telecommunications Reporting Worksheets should be sent:
Choice Wireless
7901 Flying Cloud Dr. STE 250
Eden Prairie, MN 55344

114 Billing Address and billing contact person: (Bills for Universal Service contributions will be sent to this address.)
Choice Wireless, L.C. Attn Pam Tucholke
7901 Flying Cloud Dr. Ste 250
Eden Prairie, MN 55344

**Block 3: Contributor Revenue Information**

| Filing Period — Billed revenue for January 1 through June 30 of 2000 | Total Revenue (a) | Interstate Revenue (b) | International Revenue (c) |
|---|---|---|---|
| 115 Revenue from service provided to other universal service contributors for resale | [redacted] | [redacted] | [redacted] |
| 116 Universal service contribution base revenues | [redacted] | | |
| 117 All other revenues | [redacted] | Column (b) and (c) not requested | |
| 118 Gross billed revenue from all sources (sum of above) | [redacted] | for lines 117 and 118 | |

**Block 4: CERTIFICATION: to be signed by an officer of the filer**

119 I certify that the revenue data contained herein is privileged and confidential and that public disclosure of such information would likely cause substantial harm to the competitive position of the company. I request nondisclosure of the revenue information contained herein pursuant to Sections 0.459, 52.17, 54.711 and 64.604 of the Commission's Rules. [ ]

I certify that I am an officer of the above-named reporting entity, that I have examined the foregoing report and to the best of my knowledge, information and belief, all statements of fact contained in this Worksheet are true and that said Worksheet is an accurate statement of the affairs of the above-named company for the previous calendar year.

120 Signature: Alvin M Fuhrman

121 Printed name of officer: Alvin Fuhrman

122 Position with reporting entity: President

123 Date: 12/21/00

124 This filing is: [x] Original filing [ ] Revised filing (revisions due by January 31, 2000)

Do not mail checks with this form. Send this form to: Form 499 c/o NECA, 80 South Jefferson Road, Whippany, N J 07981

For additional information regarding this worksheet contact: Telecommunications Reporting Worksheet Info (973) 560-4400 or via e-mail: Form499@neca.org

PERSONS MAKING WILLFUL FALSE STATEMENTS IN THE WORKSHEET CAN BE PUNISHED BY FINE OR IMPRISONMENT UNDER TITLE 18 OF THE UNITED STATES CODE, 18 U.S.C. §1001

USAC
UNIVERSAL SERVICE
ADMINISTRATIVE CO

# CERTIFICATION OF UNIVERSAL SERVICE FUND DE MINIMIS EXEMPTION
## September 1, 2000 Filing

I certify that I am an officer of the carrier identified below, that we have examined the FCC Form 499-S and its instructions, that we have performed the *de minimis* test in said instructions, and that to the best of my knowledge, information and belief, as a result of performing that test, we will not have a contribution amount for 2001 that exceeds the $10,000 threshold thereby exempting us from the requirement to file an FCC Form 499-S on September 1, 2000

| | | | |
|---|---|---|---|
| Filer 499 ID: (formerly TRS Company Code) | 8 _ _ _ _ _ | | |
| IRS Employer ID # (EIN). | [redacted] | | |
| Principal Communications Business *Please check only one category* (see Form 499-S Instructions pp 9-10) | ☐ CAP/CLEC<br>☐ IXC<br>☐ Paging & Messaging<br>☐ Private Service Provider<br>☐ SMR<br>☐ Other Local* | x Cellular/PCS/SMR (wireless telephony)<br>☐ Local Reseller<br>☐ Payphone Service Provider<br>☐ Satellite<br>☐ Toll Reseller<br>☐ Other Mobile* | ☐ Incumbent LEC<br>☐ OSP<br>☐ Pre-paid Card<br>☐ Shared Tenant Service Provider<br>☐ Wireless Data<br>☐ Other Toll* |
| | **If Other Local, Mobile or Toll is checked, describe contributor type:* | | |
| Legal Name of Company | Choice Wireless, LC | | |
| Complete Mailing Address | 7901 Flying Cloud Drive, Suite 250<br>Eden Prairie, MN 55344 | | |
| Name of Contact Person: | Pam Tucholke | Contact E-Mail:<br>Pam.Tucholke@quantumcomm.com | |
| Telephone Information: | Contact Phone:<br>(952) 942-7650 | Contact FAX:<br>(952) 942-5938 | |
| Officer Signature. | Alvin M Fuhrman | Printed Name of Officer:<br>Alvin Fuhrman | |

**Please see the FCC Form 499-S Worksheet Instructions on page 5 for further information and how to determine if your company meets the de minimis standard for universal service purposes.**

Please submit this form, if applicable, to:

**Form 499 Data Collection Agent**
**Attn: Lori Terraciano**
**80 South Jefferson Rd.**
**Whippany, NJ 07981**

**NOTE: If this company qualifying for the *de minimis* exemption is a RESELLER, you must notify your underlying carrier that you are not contributing directly to universal service, and you must be considered an end user by the underlying carrier.**

# ATTACHMENT 2

TENDLER

C E L L U L A R

Robert K. Tendler, Chairman

## E-911 COMPLIANCE

As the deadline for responding to the E-911 deadline approaches, and as the Chairman of Tendler Cellular, we would like to inform your company about the availability of FoneFinder®, the first autonomous GPS handset approach to location. FoneFinder-equipped phones are the complete answer for both Phase I and Phase II of the E-911 Report and Order (see www.fonefinder.com) and do so without any additional infrastructure.

Tendler Cellular has developed the first GPS in a handset, with the Audiovox CDM-9000 FoneFinder phones meeting the E-911 mandate with incredible 3-meter accuracy.

The key to FoneFinder is that it transmits GPS location via synthesized voice and DTMF tones over the voice channel direct to a PSAP or dispatch office using your existing network. This also means that with the provision of a FoneFinder handset the system is instantly deployable.

It terms of the rural carriers and compliance with the E-911 Report and Order, no longer does the rural carrier have to depend on triangulation systems where there may not be appropriate towers to get a triangulation fix. Nor do towers have to be retrofitted with anything. Nor does the carrier have to provide a back haul to the PSAP.

With FoneFinder-equipped phones the existing infrastructure is used, and for automatic location, terminals at the PSAP need only be provided with a Delorme map, a DTMF decoder and a $30 Tendler Cellular software interface (eg. $230/terminal).

What this does is give your EMTs, Police and Firemen almost free location. Better yet, it is available now.

Additionally, FoneFinder-equipped phones offer complete telematics in a handset, and have been likened to Cadillac OnStar without having to buy the car. This is because all FoneFinder phones come equipped with a protected 911 button and a roadside assistance concierge button. The 911 calls go direct to the PSAP, with the roadside assistance concierge calls going to a third party dispatch operation such as the Cross Country Group. AAA. ATX. 1800TOWTRUCK and others.

It is a feature of the FoneFinder phones that location-based services such as roadside assistance and concierge services provide revenue streams which more than offset the cost of the FoneFinder phones. Also. because of the unique capabilities of FoneFinder. carriers can expect more activations and airtime.

It should be noted that while FoneFinder is available in CDMA/analog phones. TDMA /analog phones are in design.

As the carriers undoubtedly know. the rural carrier can meet the FCC mandate by declaring the intention to go with the handset approach and by providing 50% of new phones with GPS location technology. For rural carriers this is not a lot of phones.

We believe that FoneFinder offers the simplest and most cost effective way of meeting the mandate and does so with fully integrated GPS phones available now.

Robert K. Tendler.
Chairman
Tendler Cellular. Inc.

65 Atlantic Avenue, Boston. MA 02110
Telephone 617-720-1339 • Fax 617-723-7186

# ATTACHMENT 3

## SnapTrack Announces Leading GSM Carriers Prepare for Pan-European Tests of Wireless Location Technology



**Paris - 22 June 2000**

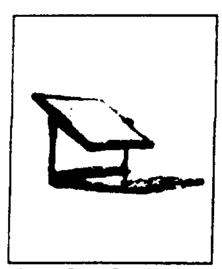
Assisted GPS-Based Location System Phase II Trials to Demonstrate SMS, Seamless Roaming

SnapTrack Inc., a wholly owned subsidiary of QUALCOMM Incorporated (Nasdaq: QCOM) and leader in wireless position location technology, today announced an international consortium of Global System for Mobile telecommunications (GSM) wireless carriers, handset suppliers, applications providers, infrastructure manufacturers and semiconductor manufacturers who are preparing to conduct an intensive evaluation of SnapTrack's breakthrough approach to wireless handset location technology.

France Telecom Mobiles is hosting the multi-country SnapTrack location technology trials, as it is interested in deploying wireless location services and technologies. The trials will demonstrate SnapTrack's functionality in a broad range of call environments and its ability to provide seamless cross-border network-to-network roaming for location services. Prototype GSM handsets will be used by SnapTrack GSM Test Group members to also test Wireless Application Protocol (WAP) services augmentation and gateway compatibility, and the efficient exchange of location information between system elements via Short Message Service (SMS).

"CMG Telecommunications' participation in the SnapTrack GSM Test Group field trials will allow us to gain valuable experience with wireless location technologies and services," said Peter Maathuis, Vice President Global Sales & Marketing of CMG Telecommunications. "CMG's expertise in wireless infrastructure systems, including SMS and WAP, will be central to the STGTG's trials, which will demonstrate CMG's commitment to providing its carrier customers with a package of highly accurate WAP-enabled wireless location systems."





SnapTrack's Wireless Assisted Global Positioning Systemä technology will enable a whole range of value-added location-based services for mobile subscribers and mobile internet users. Services include location-sensitive billing, mobile directory assistance, personal navigation, improved roadside assistance and enhanced vehicle fleet management. SnapTrack's responsiveness and accuracy will also enhance public safety for people placing emergency calls on their mobile phones.

"The Phase I GSM Test Group trials demonstrated SnapTrack's ability to provide the highly accurate location information needed for the deployment of cost-effective commercial location services in typical urban European centres - for both pedestrian and in-vehicle services," said Steve Poizner, CEO of SnapTrack. "The Phase II trials are expected to not only demonstrate SnapTrack's compatibility with SMS, but also that SnapTrack's enhanced GPS handset-based system is the only approach that can provide seamless cross-border and inter-network location services roaming. This simply cannot be done with any location system that requires network equipment modifications."

The SnapTrack GSM Test Group Phase I trials in Madrid, Spain, successfully demonstrated near-commercial location services applications in the GSM environment, with callers typically pinpointed to within 5-20 meters. During the trials, mobile users were guided to featured points of interest and to hotels, ATMs, nightclubs and tourist attractions closest to their calling locations. Recent studies by Strategis Group indicate that the wireless location services market could generate as much as $20 to $30 billion per year in revenues for European carriers and vendors by 2005.

The SnapTrack GSM Test Group consortium, formed more than a year ago, collectively supports over 30 million subscribers. Publicly disclosed members include Vodafone AirTouch Communications PLC (UK and US), BellSouth Mobility DCS (US), BT Cellnet (UK), Esat Digifone (Ireland), France Telecom (France), Omnitel Pronto Italia (Italy), T-Mobil (Germany), Telecel (Portugal) and Telefonica (Spain), and applications developer SignalSoft (UK and US). Prototype handsets will be provided to the consortium for the field trials.

Infrastructure providers CMG Telecommunications (Holland), Nortel (France) and Siemens Information

GSM Software

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and Communication Networks (Germany) will participate in the trials, as will semiconductor manufacturers Texas Instruments and Motorola. Texas Instruments and Motorola have previously announced licensing agreements with SnapTrack.

About SnapTrack's Technology

SnapTrack's personal location technology fuses the intelligence and power of networks in the mobile environment with the accuracy and coverage of the Global Positioning System. SnapTrack's thin-client Wireless Assisted GPS system improves upon conventional GPS by combining information from GPS satellites and wireless networks to accurately and reliably pinpoint a wireless phone. While traditional GPS receivers may take several minutes to provide a location fix, SnapTrack's system generally locates callers within a few seconds. Callers are typically located to within 5-20 meters in a wide range of challenging call environments where normal GPS will not work, including inside houses and moving vehicles, under heavy foliage, and in downtown urban street canyons. SnapTrack's unique Location on Demand™ feature also ensures a caller's privacy, putting location information in the hands of the user, not the network.

SnapTrack's technology products permit the design of cellular phones, pagers, PDAs, and other wireless devices that operate in multiple GPS navigation modes, allowing out-of-network location coverage and a variety of thin-client applications. SnapTrack's wireless location technology products require no additional cell sites or modifications to existing network equipment and are designed to have minimal impact on cost and handset form factor. Furthermore, SnapTrack's technology is air-interface neutral and is applicable in any two-way wireless system: cellular/PCS, satellite, or paging; 800/900 MHz or 1800/1900 MHz; GSM, CDMA, TDMA, PDC or 3G air interfaces.

# ATTACHMENT 4

# An Introduction to SnapTrack™ Server-Aided GPS Technology

## BIOGRAPHY

Mark Moeglein received his B.S. in Engineering in 1987 from Harvey Mudd College. He has been developing GPS-related systems since 1989, and has been a primary developer of the SnapTrack™ LocationServer technology since joining the company in 1996.

Norman Krasner received his B.S. in Electrical Engineering from M.I.T. in 1968 and M.S. and PhD from Stanford University in 1970 and 1974. He has worked in the fields of signal processing and communication systems design for over 30 years, including design of many spread spectrum communication systems. He was a co-founder of SnapTrack™ in 1995 and is currently V.P. of Technology.

## ABSTRACT

The distributed SnapTrack™ server-aided GPS system architecture and DSP software-based receiver solution draw from the best of GPS and wireless communications technology. The DSP-based receiver is superior to conventional correlator-based approaches in terms of cost, sensitivity, time-to-first-fix and power consumption. A smart server provides key aiding information and performs navigation solutions, minimizing incremental handset costs and providing for improved acquisition times, sensitivity, and accuracy. This paper will describe the advantages of these innovations and demonstrate the technology with a presentation of field test results.

## INTRODUCTION

SnapTrack™ has developed a distributed server-aided DSP-based processing approach to the problem of locating wireless communication devices. The key advantages to this approach, when compared to conventional GPS, are:

1. *High sensitivity.* The SnapTrack™ system can acquire and provide fixes in conditions with as much as 25dB (a factor of 300) signal attenuation or blockage. Traditional GPS technology can have difficulty acquiring signals when the attenuation exceeds 5-10 dB. This signal sensitivity improvement allows SnapTrack™-enhanced GPS to operate in difficult environments, such as most buildings, inside automobiles, under dense foliage, and in urban canyons, where traditional GPS is unreliable or unusable.

2. *Low Time-To-First-Fix.* Traditional GPS receivers require from 30 seconds to several minutes to acquire and track satellites, depending upon how much information they have previously gathered. In worst case environments, the SnapTrack™ system provides a first fix in just a few seconds. In open-sky situations, the first fix can be performed in less than a second.

3. *Low power dissipation.* SnapTrack™ technology performs *Location On Demand*, using a snapshot of data (typically 0.1 to 1 second, depending on sensitivity required), and then turns off. The entire location operation

takes only a few seconds for a "cold start" in a heavily blocked signal environment, and is significantly faster if prior information (such as local oscillator offset) is known or signal strength is high (> 135dBm). Thus, in those applications which do not require continuous high-rate positioning, the low duty cycle SnapTrack™-enhanced GPS receiver dissipates a small fraction of the power of the communication device (e.g., a portable handset) with which it is mated.

## CONVENTIONAL GPS

A GPS user positioning system can be broken into four primary functions:

(1) determining the code phases (pseudoranges) to the various GPS satellites,
(2) determining the time-of-applicability for the pseudoranges,
(3) demodulating the satellite navigation message, and
(4) computing the position of the receiving antenna using these pseudoranges, timing, and navigation message data.

Most commercial GPS receivers perform all of these operations without any external assistance. In these conventional receivers, the satellite navigation message, and its inherent synchronization bits, are extracted from the GPS signal after it has been acquired and tracked. But collecting this information normally takes thirty seconds to several minutes. Also, a high received signal level (approximately -135dBm or greater) is required from all satellites to be used in the navigation solution for the 18 second duration of subframes 1-3.

## DISTRIBUTED SYSTEM CONCEPT

The SnapTrack™ server-aided system architecture distributes the four primary functions described above between a GPS reference receiver, a location server, and a wireless GPS-enabled device (later referred to as a handset.) The basic system model is described in Figure 1.

A GPS reference receiver gathers navigation message and differential correction data for all satellites in view. In another system configuration, the GPS reference receiver may be replaced by a network of reference receivers to provide coverage for a wide area, such as the continental U.S.

The location server receives and stores data from the GPS reference receiver (or network), provides aiding data to mobile units, and performs navigation solutions upon receipt of pseudorange measurements from the handset.

The aiding data, sent to each handset on-demand, is generally a list of satellites in view from the handset and their relative Doppler offsets. (Estimated Doppler can be improved by using the location of the base station communicating with the hand-held device as an approximate handset location.) This small message (approximately 50 bytes) is all the handset needs to know from the location server to extract pseudorange information from its short snapshot of GPS data.

The server also has access to a terrain elevation database. This allows it to perform accurate altitude aiding for ground-based applications, a capability that is impractical if the navigation solution is performed at the mobile. The terrain elevation provides essentially an extra range measurement, improving reliability and accuracy.

The server is able to mitigate multipath and reflected signal effects using a sequential measurement optimization (SMO) technique. The server also handles cross-correlations from strong signals onto the PRN codes of weaker satellites, as well as correcting for atmospheric delays.

In general, the location server is remote from the final application, such as service centers providing display and operator services.

The wireless GPS-enabled device can track far weaker GPS signals than a conventional GPS receiver, because it does not need to decode the navigation message. But

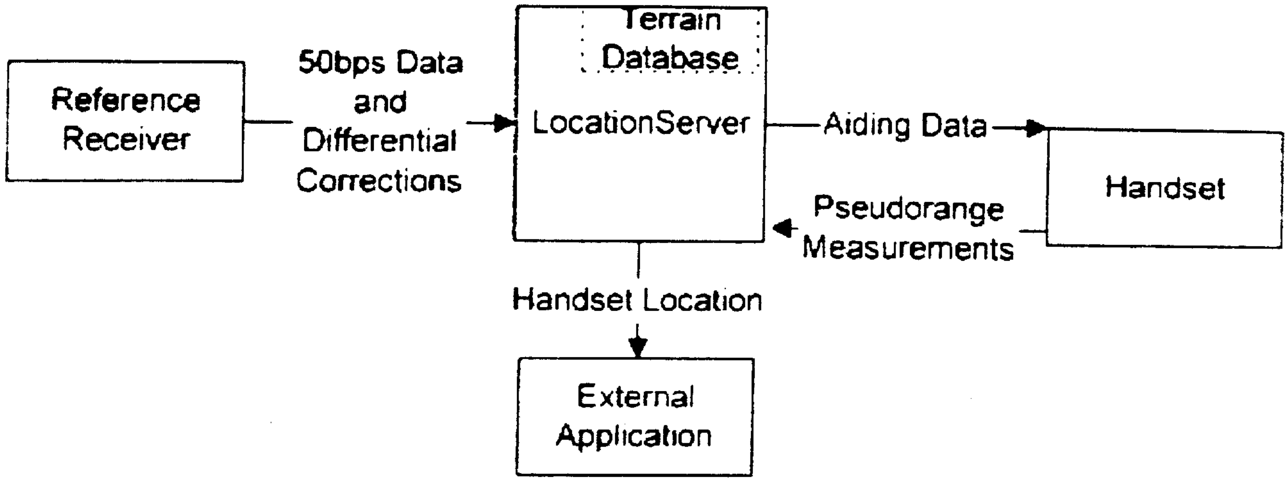


*Figure 1 Basic system model*

rapidly and accurately finding these weaker signals requires a powerful signal processing element to search over the large number of PRN codes, times-of-arrival, and offset frequencies (due to Doppler errors and local oscillator frequency errors). The DSP-based process for determining pseudoranges is described later in this paper.

**CONVENTIONAL GPS CORRELATION TECHNIQUES**

Conventional GPS receivers use correlation methods to compute pseudorange. A classic hardware correlator-based receiver multiplies the received signal by a stored (or generated) replica of the appropriate PRN code and then integrates, or lowpass filters, the product to obtain a peak correlation signal. The initial determination of the presence of a correlation peak is termed "acquisition."

Once a signal is acquired, the process enters the tracking mode in which the PRN code is removed, or "despread." This signal has a narrow bandwidth, commensurate with the 50 bit per second navigation message modulated onto the GPS waveform. At this point, the navigation message may be reliably demodulated if received signal strength is above approximately -135dBm for the duration of the message being received.

The conventional acquisition process is very time consuming, especially if received signals are weak. To improve acquisition time, most GPS receivers utilize a multiplicity of correlators (nominally ~36 for a 12-channel receiver), which allows a parallel search for correlation peaks as a function of time-of-arrival, PN code, and frequency offset. Recently, massively parallel correlators (on the order of 240) have been used to improve acquisition speed and sensitivity. In excess of 8000 correlators would be required to match the speed and sensitivity of the SnapTrack™ server-aided GPS fast convolution processing technique. And the processing speed or this technique will improve as DSP technology advances.

**HANDSET ARCHITECTURE**

Figure 2 is a "handset view" of the SnapTrack™ server-aided GPS system. Note that the conventional tracking loops are replaced by snapshot memory and fast convolution processing.

At the request of either an external application, or the handset user, the server sends information on satellites in view at the handset's approximate location, including Doppler predictions. After a snapshot of GPS satellite RF data has been stored in the handset memory, the DSP processes the data and returns pseudorange measurements to the server, along with other statistical information. This snapshot approach allows the handset to gather GPS data when it is not transmitting, thus eliminating potential self-interference.

Each of the messages between the handset and the location server is small (50-100 bytes). This represents a significant reduction in required communications bandwidth when compared to delivering differential corrections, almanac, ephemeris and/or satellite trajectory data to the handset.

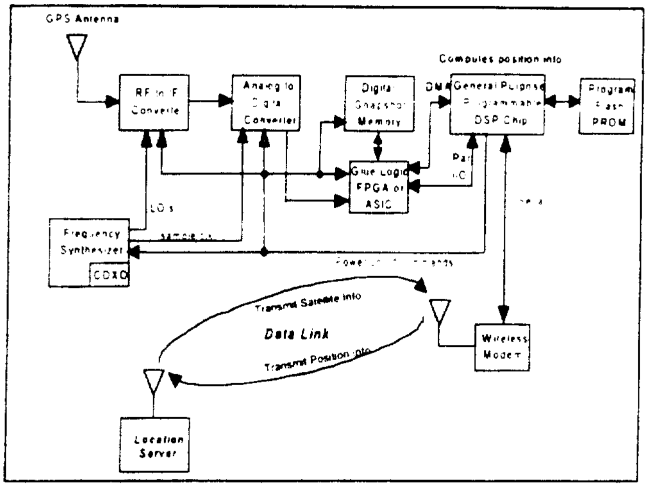


Figure 2 Block diagram of DSP-based GPS processing system

FFT-based fast convolution techniques provide higher sensitivity and faster acquisition speed by performing a large number of FFT operations together with special pre- and post-processing operations [1]. It is expected, in a worst-case example, that pseudorange in the DSP will require approximately 5 seconds, with much faster performance in situations with higher (> -135dBm) signal strength or DSP speed.

In the system described in Figure 2, received data is down-converted to a suitably low (~2MHz) intermediate frequency, digitized and stored in a buffer memory. This data is then operated upon using a programmable DSP IC. Unlike continuously tracking hardware correlator-based receivers, this "snapshot" processing technique is not subject to the fluctuating signal levels and changing nature of the signal environment.

Each received GPS signal (C/A code) is constructed from a high rate (1 MHz) repetitive pseudorandom noise (PRN) pattern of 1023 symbols, commonly called "chips." These "chips" resemble the waveform shown in Figure 3A. Further imposed on this pattern is low rate data, transmitted from the satellite at 50 baud. All of this data is received at a very low signal-to-noise ratio as measured in a 2 MHz bandwidth. If the carrier frequency and all data rates were known to great precision, and no data were present, then the signal-to-noise ratio could be greatly improved by summing successive frames. For example, there are 1000 C/A code epochs over a period of 1 second. The first such epoch could be coherently added to the next, the result added to the third, etc. The result would be a signal having duration of 1023 chips. The phasing of this sequence could then be compared to a local reference sequence to determine the relative timing between the two, thus establishing the pseudorange. Doppler and local oscillator uncertainty complicate this process. The server reduces these uncertainties by providing Doppler estimates.

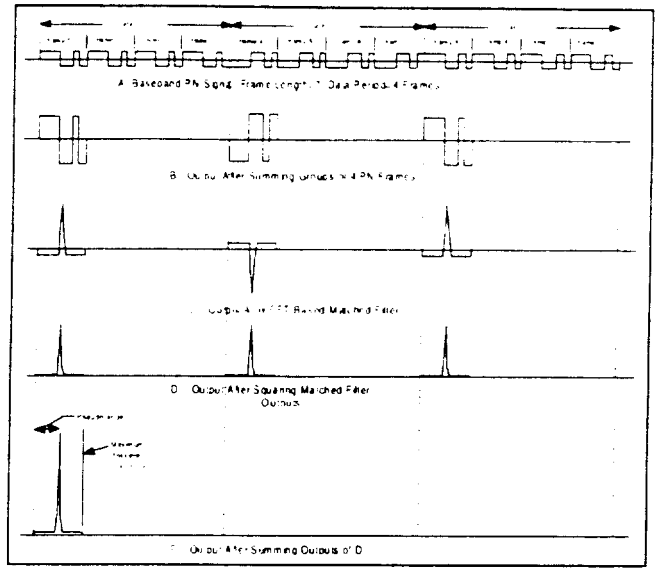


Figure 3 Coherent and incoherent summation with matched filtering.

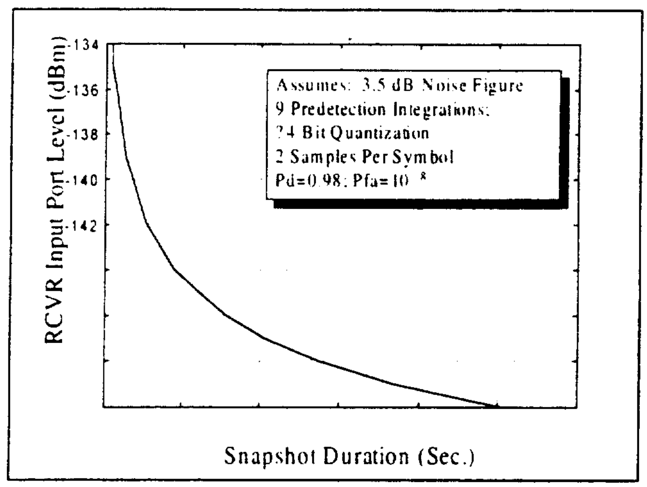


Figure 4 Predicted Sensitivity in Thermal Noise

The above process is carried out separately for each satellite in view from the same set of data in the snapshot memory, since, in general, the GPS signals from different satellites have different Doppler frequencies and the PRN patterns differ from one another.

The presence of 50-baud data superimposed on the GPS signal limits the coherent summation of C/A code epochs to a period of 20 msec. That is, at most 20 one-millisecond-long epochs may be coherently added before data sign inversions prevent further coherent summation (unless this data is provided by the server). Additional processing gain may be achieved through summation of the magnitudes (or squares of magnitudes) of the coherently summed intervals, providing the sensitivity and accuracy shown in the curves of Figures 4 and 5.

A calibrated single-satellite GPS simulator and a demonstration system designed by SnapTrack™ were used to experimentally verify the performance predicted in Figure 4. The 20-meter accuracy predicted by Figure 5 with a 1-second snapshot and −150dBm signal strength was also demonstrated in later field testing.

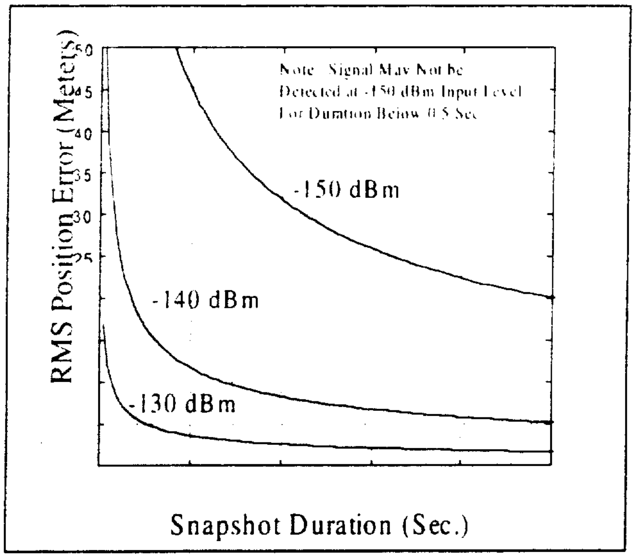


Figure 5 Predicted accuracy in thermal noise, HDOP=1.5

## FIELD TEST RESULTS

The SnapTrack™ demonstration system was used extensively for field tests designed and audited by independent wireless carriers. Environments ranging from open sky to in-vehicle, indoor and urban canyon were investigated.

Table 1 summarizes test results from seven test locations visited over the past year. These selected results are representative of a much broader range of tests.

The test setup consisted of a 12-channel reference receiver transmitting reference data to a PC-based location server, which communicated with a SnapTrack™ sensor via modem over an analog cellular phone connection. The SnapTrack™ sensor used an off-the-shelf active patch antenna, and a long cable, which allowed testers to place the antenna in hard-to-reach places. Preliminary results indicate similar performance with a "micro-helix" passive antenna, which is more suitable for handset integration[2].

| Environment | Conditions | Yield | 68.3% Horizontal Error |
|---|---|---|---|
| Outdoors | Open site | 100% | 4 meters |
| Urban Street, Shinbashi, Tokyo | 2-10 story buildings, narrow streets and alleys | 100% | 15 meters |
| Inside Sport Utility Vehicle | Parking lot surrounded by red wood trees and two-story buildings. Antenna placed on inside shoulder | 100% | 17 meters |
| Two Story House | Center of basement | 100% | 20 meters |
| Two-Story Office Building | 1st floor, interior room | 94% | 22 meters |
| Urban Canyon, Denver, CO | 20-30 story buildings, wide streets, altitude aided | 98% | 29 meters |
| 50-Story Building | Glass/Steel building, 21st floor, 14 ft from outside wall | 89% | 84 meters |

Table 1 Field test results summary

The system was operated such that no information was carried over for each successive sample. Thus, each successive snapshot can be considered an independent "first fix." A more detailed description of each location (with the exception of the outdoor, open sky environment) follows, with plots of the horizontal "shot pattern" from each location.

Figure 6a One-lane urban road

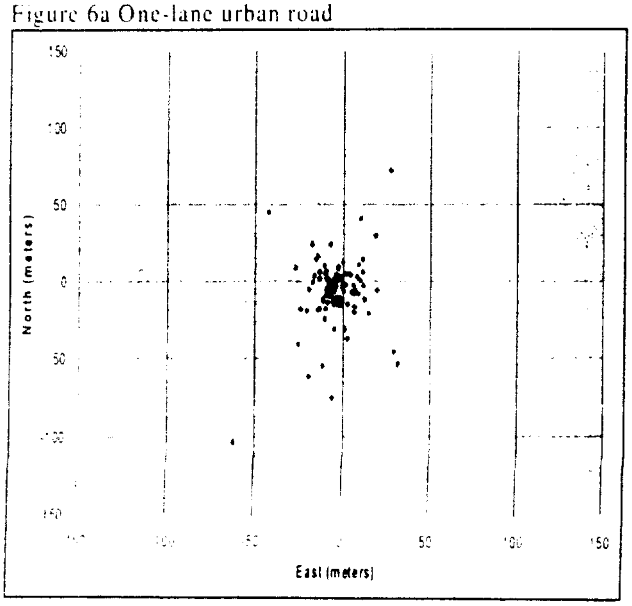


Figure 6b Shot pattern, one-lane urban road

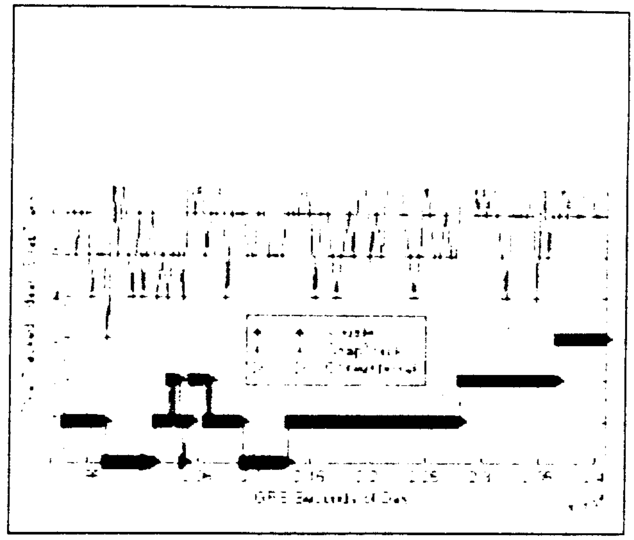

Figure 6c Satellites tracked by SnapTrack sensor and conventional hand-held

**Test location: one-lane urban road**

A Japanese wireless carrier selected the site depicted in Figure 6a to represent a fairly typical Tokyo environment. The antenna was placed approximately 3 feet above the ground on the side of a one-lane road, surrounded by 2-10 story buildings.

A conventional handheld GPS receiver was used for comparison purposes. This receiver was allowed to operate continuously throughout the data collection, resting horizontally (antenna facing the sky) near the antenna used for the SnapTrack handset.

Results in Figure 6c show the conventional receiver tracking 14.3% of the satellites in view over the data collection period, while the SnapTrack handset was able to acquire 65.3% of satellites on "cold starts" throughout the data collection interval.

**Test location: sport utility vehicle**

Figure 7a shows one of several test vehicles used in SnapTrack™ parking lot in-vehicle testing. This lot has moderate blockage from a two-story building, as well as several redwood trees overhead. Resultant accuracy is similar to that observed in most indoor tests.

Figure 7a Sport utility vehicle

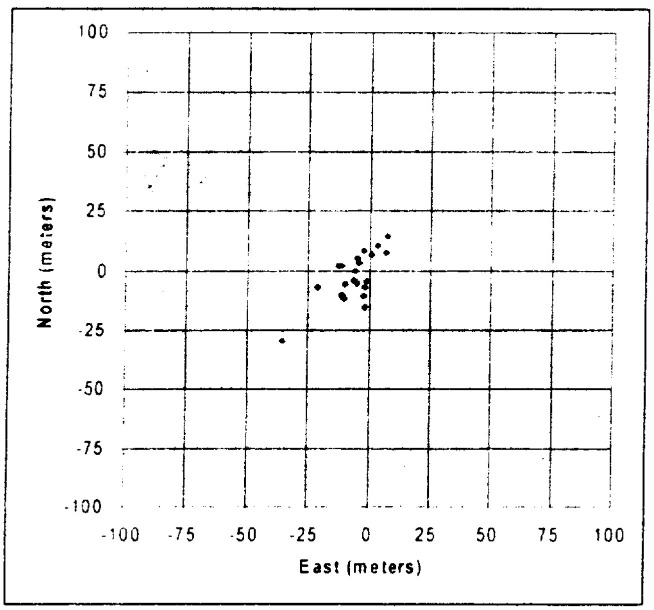


Figure 7b Shot pattern, sport utility vehicle

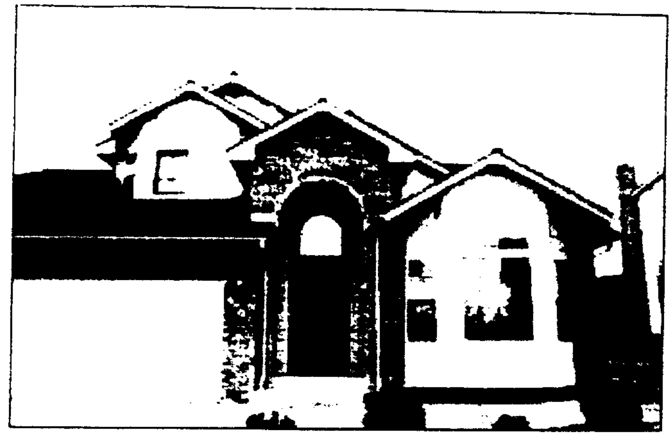

Figure 8a Westminster (Denver), Colorado house

Figure 8b GPS Antenna at center of basement

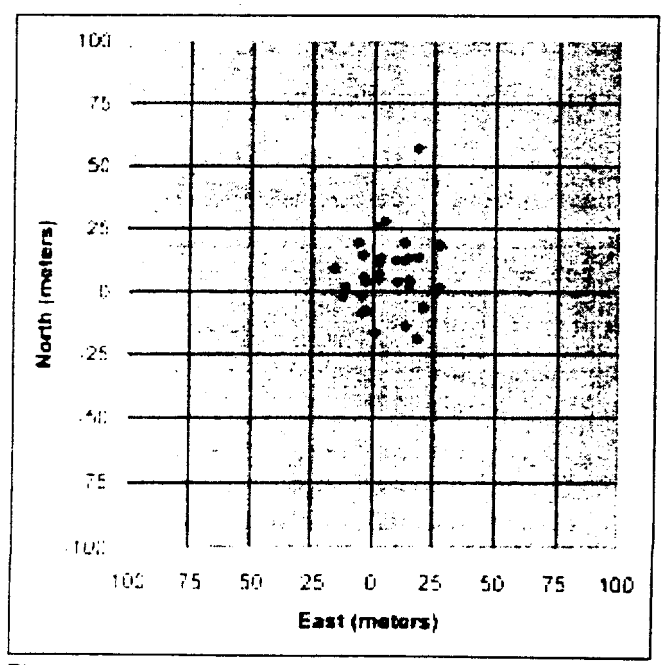


Figure 8c Shot pattern, basement of two-story house

**Test location: basement of two-story residence**

U.S. West selected the house in Figure 8a as a sample residence in the Denver area. As shown in Figure 8b, the antenna was placed in the center of the basement. (The 5-watt analog phone had to be placed outside to maintain enough signal strength for data connectivity.) Figure 8c shows system performance in this location.

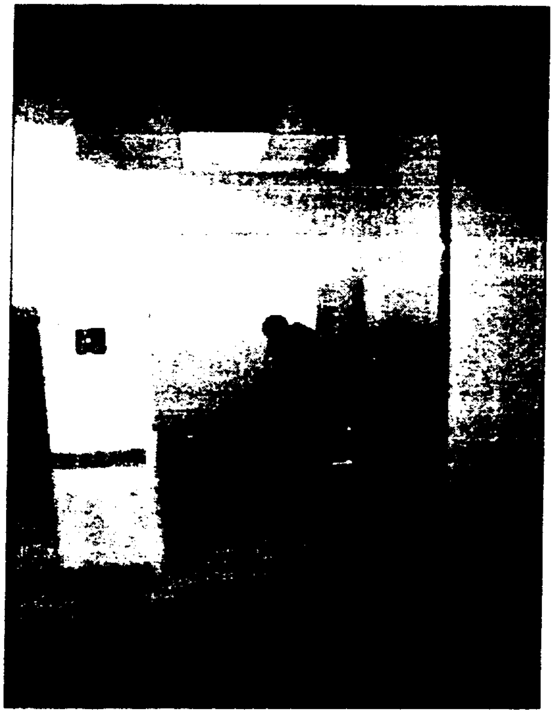

Figure 9a Two-story brick building, interior first floor

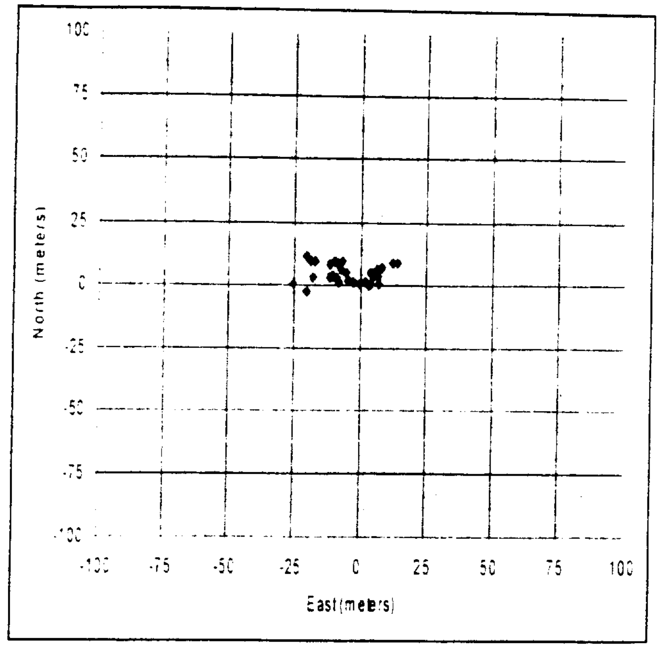


Figure 9b Shot pattern, first floor interior room

**Test Location: Two-story office building, interior**

Figure 9 shows the location and results of this test in a two-story commercial brick building. As expected, the accuracy is comparable to most residential locations. The test equipment was placed in an interior first-floor room.

**Test location: urban canyon**

Figure 10a illustrates a somewhat typical downtown environment. Figure 10b and Figure 10c demonstrate server-aided system performance in this environment with and without altitude aiding. In this test case, altitude aiding resulted in a 30% accuracy improvement. In weaker signal environments, altitude aiding is very important, improving satellite geometry, as well as providing a reliable extra measurement in the navigation solution.

Figure 10a Urban canyon, downtown Denver

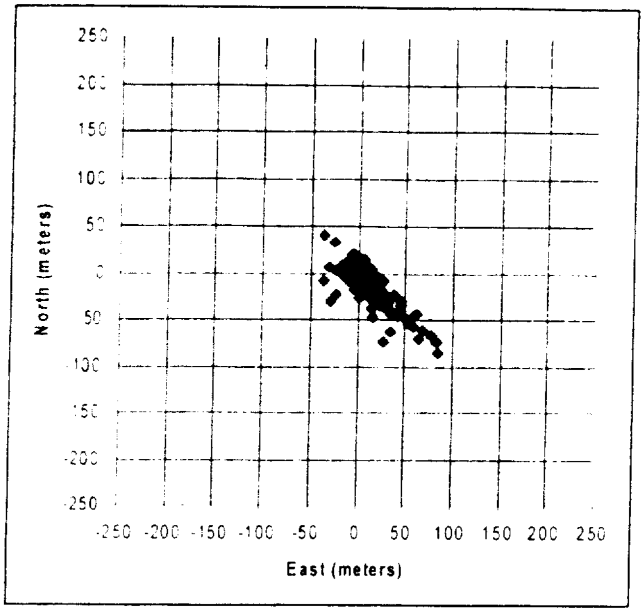


Figure 10b Shot pattern, urban canyon, altitude aided

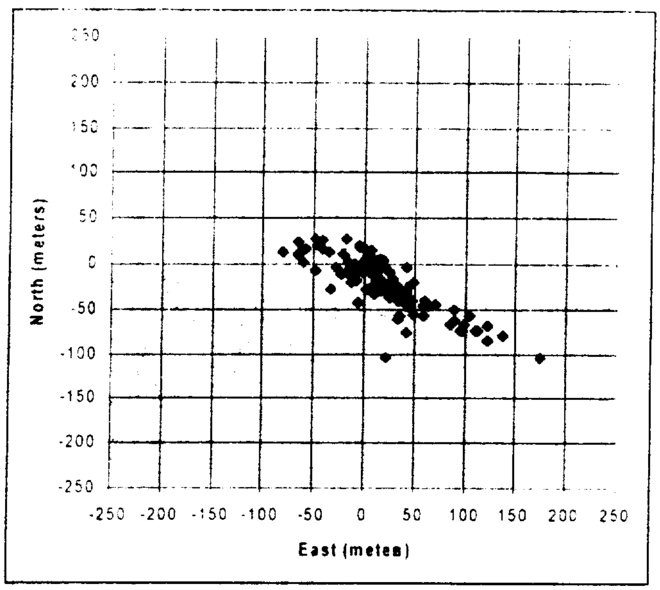


Figure 10c Shot pattern, urban canyon, unaided

**Test Location: 50-Story Glass/Steel Building, 21st floor, 14 feet from outside wall**

Figure 11a illustrates a signal environment with poor signal strength and long multipath. In previous tests, either the signal strength (and therefore often the geometry) or path length differences were poor. In this case, 14 feet from the outside wall on the 21st floor of this building, both problems were evident, creating greater position biases due to reflections from a south-facing building, as shown in Figure 11b.

Figure 11a Fifty story glass/steel building

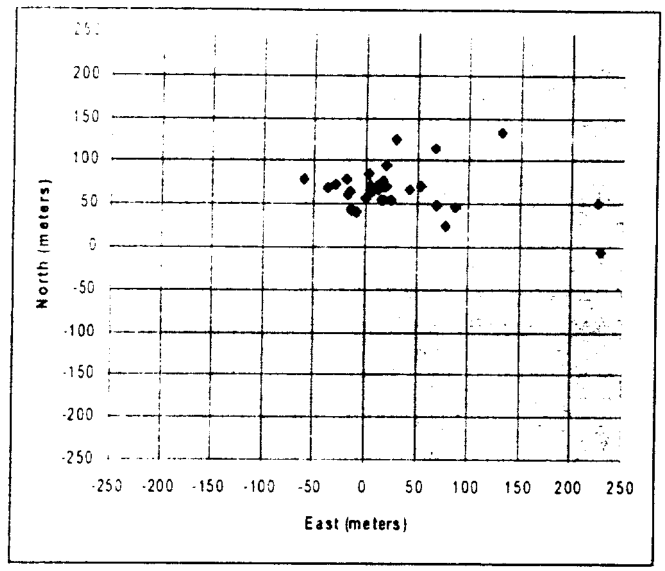


Figure 11b Shot pattern, inside 50-story building

**Denver E-911 Trial**

SnapTrack™ provided the enabling GPS technology for a recent end-to-end wireless E-911 trial conducted in the Denver area. Figure 12 is a good illustration of how the SnapTrack™ distributed system architecture can be used.

For this demonstration, a single reference receiver provided reference information to a location server. The SnapTrack™ sensor was programmed with the Mobile Identification Number (MIN) of an accompanying digital phone, so that their separate calls could later be matched by the SignalSoft Service Control Point (SCP). (In this case, the analog phone provided communication services to the SnapTrack sub-handset and the digital phone

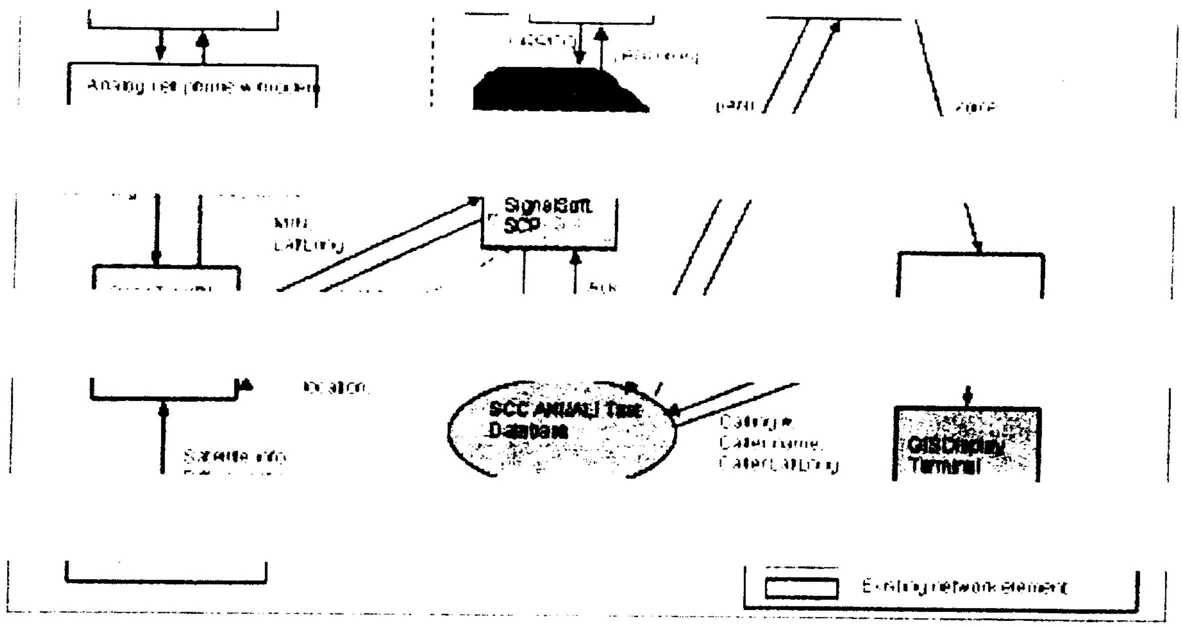


Figure 12 Denver E-911 trial system

provided E911 functionality.) When the mobile user placed a call to the Public Safety Access Point (PSAP), the two pieces of information were combined into a single call by the SCP when presenting the information to the SCC database. This database provided call routing instructions for the digital cell phone's 911 voice call. The SCP was able to determine which PSAP should receive each call using the location information from the LocationServer and a digital map of PSAP coverage boundaries. The SCC ANI/ALI database also provided the handset location to the selected PSAP, pin-pointing the caller location on a GIS map display.

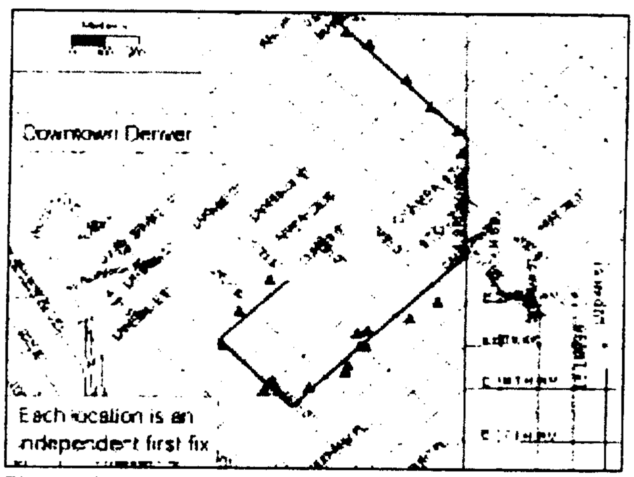


Figure 13 Driving out of urban canyon

Figure 13 shows results from driving through an urban canyon in downtown Denver. The small clusters of points in Figure 13 are located near stop lights on the route out of downtown. Figure 14 illustrates the results of dynamic vehicle testing on an urban highway.

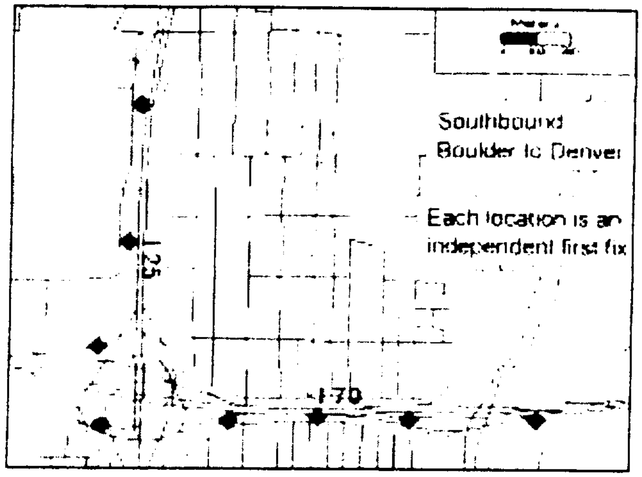


Figure 14 Urban highway

## SUMMARY

SnapTrack™ server-aided GPS improves upon conventional GPS performance by sharing processing and database functions between the mobile GPS receiver/processor (the client) and a remote infrastructure (the server and reference network). The result is a highly sensitive, cost-effective, low-power, GPS receiving system that provides first fixes in a few seconds from a cold start, even where conventional GPS is unworkable or unreliable.

Audited field test results demonstrate accuracy of 3-100 meters (depending on degree of blockage), which is substantially better than the 125 meters required by the recent FCC E911 mandate, even in severe blockage and multipath environments.

## REFERENCES

[1] Krasner, Patent 5,663,734

[2] Krasner, Wolf, Bell, and Wilson, "SnapTrack Enhanced GPS Technology: Field Test Results Using Prototype GPS Handset Antenna, Including the Impact of User Head Blockage.", submitted to the T1P1.5 GSM Working Group, August 17, 1998